Getting connected:
Both associative and semantic links structure semantic memory for newly learned persons

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Abstract

The present study examined whether semantic memory for newly learnt people is structured by visual co-occurrence, shared semantics, or both. Participants were trained with pairs of simultaneously presented (i.e., co-occurring) pre-experimentally unfamiliar faces, which either did or did not share additionally provided semantic information (occupation, place of living etc.). Semantic information could also be shared between faces that did not co-occur. A subsequent priming experiment revealed faster responses for both co-occurrence/no shared semantics and no co-occurrence/shared semantics conditions, relative to an unrelated condition. Strikingly, priming was strongest in the co-occurrence/shared semantics condition, suggesting additive effects of these factors. Additional analysis of event-related brain potentials yielded priming in the N400 component only for combined effects of visual co-occurrence and shared semantics, with more positive amplitudes in this relative the unrelated condition. Overall, these findings suggest that both semantic relatedness and visual co-occurrence are important when novel information is integrated into person-related semantic memory.

Keywords: learning, semantic priming, event-related potentials, face recognition

Introduction

When we get to know new people, it is not only important to remember their face and name, but also to learn semantic information about the respective person (e.g., about occupation, place of living, or favorite leisure activities). Evidence from neuropsychological studies points to a degree of domain-specificity for person-related semantic memory. Thus, knowledge about people can be impaired without a generalized semantic memory deficit for living things (Ellis, Young, & Critchley, 1989), and such impairment is presumably related to damage to the right-hemispheric temporal lobe (Thompson et al., 2004; see also Tranel, Damasio, & Damasio, 1997). For healthy participants access is usually fast and efficient once the respective representations have been established, even though a massive amount of information is stored in our person-related semantic memory. Such efficiency argues for an economically arranged structure of representations, with structure in this context referring to the organizing principles underlying the architecture of representations.

To date, the most influential account describing the organization of person-specific knowledge is the model by Burton, Bruce, and Johnston (1990), which utilizes an Interactive Activation and Competition architecture (McClelland & Rumelhart, 1981; McClelland, Rumelhart, & Hinton, 1986). This model suggests a categorical structure of semantic person memory. According to this view, any known person is represented by a so-called Person Identity Node (PIN), which becomes activated as a consequence of activation passing from perceptual representations for this particular person (e.g. so-called Face or Name Recognition Units). Once PIN activation exceeds a certain threshold, the person is classified as being familiar. Moreover, PINs act as gateways to semantic information (e.g., a person's occupation), which is stored in so-called Semantic Information Units (SIUs). Importantly, SIUs are not specific to any single person, but are connected to the PINs of other people who share particular semantic information as well. For instance, all actors will be connected via a common 'actor' SIU. Accordingly, semantic information belonging to a specific person (e.g., occupation, place of living etc.) is distributed across a number of different SIUs, which are in turn shared by all people who posses the respective attributes.

In contrast to this account, others suggested that semantic information about a specific person is stored in one single unit (a so-called Biographical Idiosyncratically Organized Gnostic, or BIOG, unit) exclusively linked to a representation of that person (Barry, Johnston, & Scanlan, 1998). This suggestion may be seen as standing in the tradition of holistic rather than distributed representation of semantic information (e.g., Collins & Loftus, 1975; see Hutchison, 2003, for a review on holistic versus distributed models of semantic priming). Representations of individual people are thought to be connected via direct links established by co-occurrence. Thus, according to this view, our person-related knowledge is not organized according to shared semantics, but according to associative links that are formed for people we typically see together (see also Ellis, 1992).

The question of how exactly semantic person memory is structured has been addressed by attempting to identify the types of relatedness (such as categorical versus associative) between representations of people. A common experimental technique to examine effects of semantic relatedness is the semantic priming paradigm (McNamara, 2005; Meyer & Schvaneveldt, 1971). In the context of person-related semantic priming, reaction times are typically measured while participants perform a familiarity task, i.e., they decide whether a presented face or name is familiar or not (Bruce, 1983; for a recent review, see Wiese, 2011). These targets are preceded by prime stimuli, which can be either related to the second (or target) stimulus (e.g., Angelina Jolie → Brad Pitt) or not (e.g., John Lennon → Brad Pitt). The standard finding is that participants are faster to make a familiarity decision about a target when it is preceded by a related prime (Bruce, 1983; Bruce & Valentine, 1986).

The IAC model (Burton et al., 1990) assumes that shared semantic information is the basis for semantic priming. In the example above, the presentation of Angelina Jolie's name or face will pre-activate the PIN of Brad Pitt, because the two are interconnected via shared semantic units containing categorical information (e.g., both are 'actors'). By contrast, if semantic information is not shared but stored in separate units for each individual, such categorical priming should not exist (Barry et al., 1998; Ellis, 1992). Instead, only people who regularly co-occur, and are therefore connected via direct links, should prime each other. In this example, of course, both mechanisms can explain priming, as Angelina Jolie and Brad Pitt not only share semantic information, but also regularly co-occur.

To decide between these alternatives, researchers have tried to demonstrate purely categorical priming, which, if existent, would support the IAC view. For that purpose, persons are combined to prime/target pairs who do not appear together but share categorical (i.e., mostly occupational) information. Thus, while Angelina Jolie and Brad Pitt are both highly associated (because they co-occur regularly) and categorically related (since both are Hollywood actors), it is possible to combine two actors who are not associated because they never appeared in the same movie (such as Hugh Grant and Brad Pitt). While initial studies did not observe priming for categorically related pairs (Barry et al., 1998; Young, Flude, Hellawell, & Ellis, 1994), a number of more recent experiments demonstrated this effect (Carson & Burton, 2001; Stone, 2008; Stone & Valentine, 2007; Wiese & Schweinberger, 2008, 2011). The typically observed "associative boost", which reflects stronger priming for associated (e.g., Jolie → Pitt) relative to purely categorical pairs (e.g., Grant → Pitt) has been explained by the assumption of a higher amount of shared semantic information in highly associated pairs (e.g., Angelina Jolie and Brad Pitt are not only both actors, they are also both Americans etc.).

As in the above example, semantic priming in person recognition has been typically examined with famous faces or names as stimuli. Critically, this procedure has an important drawback. Although it is feasible to create purely semantic pairs, it is hardly possible to combine famous people into purely associative pairs, because celebrities that co-occur almost inevitably also share semantic information. It is therefore not easy to test whether priming based purely on co-occurrence exists. This problem can be elegantly circumvented by using laboratory learning paradigms, which give the experimenter complete control over both shared semantic information and co-occurrences of pre-experimentally unfamiliar persons. Although the application of learning paradigms therefore seems particularly promising, to our knowledge only one such study exists. Vladeanu, Lewis, & Ellis (2006) trained participants with pairs of simultaneously presented (computer-generated) faces that either shared or did not share semantic features (such as occupational information). In addition, faces that did not co-occur could share semantic information. The authors reported significant facilitative effects of co-occurrence in a subsequent priming experiment for both semantically related and unrelated pairs, and an additional effect of semantic relatedness for the co-occurring but not for the non-co-occurring pairs.

From this finding, one might conclude that visual co-occurrence is a prerequisite for priming, which may be further strengthened by shared semantics. It should be noted, however, that the experimental parameters chosen for this study, such as a long prime/target stimulus-onset asynchrony (SOA) of 1500 ms, complicate the interpretation. Long prime/target SOAs typically promote the use of expectancy-based strategies (see e.g., Neely, Keefe, & Ross, 1989). Participants may have been able to consciously predict the specific target with which a prime face was presented during training, thus probably enhancing the speed of the familiarity decision when prime/targets pairs were related via co-occurrence. Such strategic effects, however, are typically interpreted as being more closely related to episodic than semantic memory and accordingly do not reflect the structure underlying semantic memory (see e.g., Hutchison, 2003; McRae & Boisvert, 1998; Neely, 1977; Wiese, 2011). Furthermore, it is known from the domain of word priming that substantially more extensive training periods than those used by Vladeanu and colleagues (2006) are necessary to obtain behavioural effects on the basis of newly established representations in semantic memory (see e.g., Dagenbach, Horst, & Carr, 1990). In the present study, we aimed at providing evidence for semantic priming of newly established knowledge representations in person recognition largely independent of strategic factors, which would be more directly relevant for the question of how semantic person memory is organized.

While behavioural measures such as response times can only capture the outcome of a cascade of cognitive subroutines, the high temporal resolution of event-related brain potentials (ERPs) allows disentangling these sub-processes. ERPs are voltage changes measured in the EEG time-locked to a certain event, such as the presentation of a stimulus. Of particular importance for the present purpose is the so-called N400 ERP component (Kutas & Federmeier, 2011; Kutas & Hillyard, 1980), which has been widely used to study semantic priming (e.g., Bentin, McCarthy, & Wood, 1985). In person recognition, N400 effects, reflecting more negative amplitudes for unrelated relative to related targets between approximately 300 to 600 ms, have been repeatedly observed for associatively related celebrities (Schweinberger, 1996; Schweinberger, Pfütze, & Sommer, 1995; Wiese & Schweinberger, 2008). For purely categorical priming, N400-like effects have also been detected in short (i.e., 33 ms) but not long (1033 ms) SOA conditions (Wiese & Schweinberger, 2011). In line with these results, the N400 priming effect in person recognition has been interpreted as reflecting access to semantic memory codes for people (Schweinberger & Burton, 2003). To our knowledge no ERP study exists that examined priming for people who are related via visual co-occurrence alone.

On the basis of the above-cited literature, the aims of the present study were two-fold: First, we wanted to test whether priming based on pure co-occurrence exists in person recognition. As described above, although visual co-occurrence has been repeatedly suggested as the crucial mechanism underlying associative priming, no previous study obtained unequivocal evidence for this idea. Evidence for priming exclusively based on visual co-occurrence would strengthen this position, and argue against the suggestion that representations of familiar people in person-related memory are solely linked via shared higher-order semantic units. Second, we wanted to examine whether N400 effects previously observed for highly associated prime/target pairs reflected relatedness via co-occurrence or via (large amounts of) shared semantic information. For that purpose, we conducted a training study, in which pre-experimentally unfamiliar faces were learnt to visually co-occur and/or share semantic information. In a subsequent priming experiment, both behavioural and ERP effects of purely categorical relatedness, pure visual co-occurrence, and combinations of these factors were tested.

Methods

Participants

The tested population consisted of 20 undergraduate students from the University of Jena (15 female, mean age = 23.4 y. +/- 3.2 SD). All participants reported normal or corrected-to-normal vision and were right-handed according to a modified version of the Edinburg Handedness Inventory (Oldfield, 1971). None reported neurological or psychiatric disorders, and none received central acting medication. Participants either received course credits or a monetary reward of 5 Euro/h. All gave written informed consent to participate, and the study was approved by the Ethics Committee of the Faculty of Social and Behavioral Sciences at Jena University.

Stimuli

The stimuli consisted of 160 pictures of pre-experimentally unfamiliar young adult faces (50% female respectively), taken from a full-frontal position and showing neutral expressions. Images were taken from the Center for Vital Longevity face database (Minear & Park, 2004) and edited using Adobe Photoshop™. Faces were cut out, such that clothing and background information was removed, converted to grayscale, and placed in front of a uniform black background. All images were cropped to a frame of 170 x 216 pixels, resulting in viewing angles of 3.8° x 4.8° at a viewing distance of 90 cm. All stimuli were presented on a 19” CRT computer monitor using E-Prime™.

Procedure

The experiment consisted of four training sessions and a final priming experiment with EEG recording, on five consecutive days. During each of the four training sessions, participants were familiarized with 20 novel faces, with two stimuli presented simultaneously next to each other on the screen (see figure 1). For each face, a unique written name was presented. In addition, each face was combined with written semantic information presented below the face images about the place of living (German cities, e.g., Freiburg, Potsdam, Magdeburg, Lübeck), occupation (e.g., museum guide, florist, hospital nurse, lawyer), favourite spare-time activity (e.g., scuba diving, Yoga, ancestry research, figure skating) and favourite singers (e.g., Robbie Williams, Aretha Franklin, Phil Collins, Frank Sinatra) of the depicted person. Semantic information of the two faces on the screen was identical in half of the trials, but was completely non-overlapping in the other half of the trials. Instead, in this other half of trials, semantic information for each presented face was identical to that for one other face in the set. Assignment of face stimuli to learning conditions (same/different semantic information) was counterbalanced across participants.

Each of the four training sessions consisted of five learning blocks, which were each directly followed by test blocks. During learning, all face pairs and the additional written information was presented for 25 s respectively, and participants were instructed to memorize the faces and the presented information for later testing. Each face pair was followed by a fixation cross for 1500 ms. In the directly following test blocks, each individual face was presented once in the middle of the screen, and participants were asked to choose the correct answer either about the person’s name or about one of the four semantic information units from four alternatives via key presses, and feedback about the accuracies of the response was provided. Stimuli remained on the screen for 8.5 s, during which a response was required. If no key was pressed in that time interval, a message motivating participants to respond faster was displayed. After each stimulus, a fixation cross was presented for 1.5 s. In the course of a whole training session, each face pair was presented five times together with the respective personal information during learning, and across test phases all five information units were tested for each face. At the end of each learning session, a final test was conducted, during which all faces were presented again alone on the screen, and each of the five information units was tested in a four alternative forced-choice test.

The fifth session consisted of two parts. First, each of the 40 face pairs learned in sessions 1 to 4, together with the corresponding semantic information, were presented again for 25 s each, and participants were asked to memorize both the faces and the written information. After that, each of the 80 learned faces was presented alone, and participants had to pick the correct name and information units from four alternatives via button presses. Again, feedback about the accuracy of the response was provided. Each stimulus was presented for 8.5 s and was followed by a fixation cross presented for 1.5 s.

Second, a priming experiment was carried out. Each of the 80 learned faces was presented 6 times as a prime stimulus, and three times as a target. In addition, 80 new faces were each presented three times as target stimuli, and the task of the participants was to indicate as fast and accurately as possible whether the respective target face was familiar or not. In the 240 trials with familiar target faces, prime/target pairs were combined to (i) 60 pairs that co-occurred during training and shared semantic information, (ii) 60 pairs that co-occurred during training but did not share any semantic information, (iii) 60 pairs that did not co-occur during learning but shared semantic information, and (iv) 60 unrelated pairs that neither co-occurred nor shared semantic information. Faces presented together during training that shared semantic information were used as primes and targets for the co-occurrence/shared semantics (i.e., prime and target were presented in the same learning trials during training) and for the no co-occurrence/no shared semantics conditions (i.e., prime and target were presented in different learning trials during training). Faces presented in pairs with different semantic information during training were used as primes and targets for the co-occurrence/no shared semantics (i.e., prime and target were presented together in the same learning trials during training) and in the no co-occurrence/shared semantics conditions (i.e., prime and target were presented in different learning trials during training, but shared semantic information; see also figure 1). Prime faces were presented for 100 ms, followed by a fixation cross for 100 ms, and a target face, which was presented for 1000 ms. Each trial ended with the presentation of a fixation cross for 2000 ms. Key assignment was counterbalanced across participants.

EEG recording and analysis

During the priming experiment, 144-channel EEG was recorded with a BioSemi Active II system (BioSemi, Amsterdam, Netherlands). The active, sintered Ag/AgCl-electrodes used were mounted in an elastic cap. Recording sites corresponded to the BioSemi 128-channel arrangement, with 16 additional electrodes situated below the standard positions at inferior occipito-temporal and temporal sites. EEG was recorded continuously with a 512-Hz sample rate from DC to 155 Hz. Note that BioSemi-systems work with a "zero-ref" setup with ground and reference electrodes replaced a so-called CMS/DRL circuit (cf. to http://www.biosemi.com/faq/cms&drl.htm for further information).

Contributions of blink artifacts were corrected using the algorithm implemented in BESA 5.3 (MEGIS Software GmbH, Graefelfing, Germany). EEG was segmented from 200 ms before until 1200 ms after prime onset. The 200 ms before prime onset served as a baseline. All trials with nonocular artifacts, saccades and incorrect responses were discarded using the BESA artifact rejection tool with an amplitude threshold of 100 µV and a gradient criterion of 75 µV. Segments were averaged separately for each experimental condition, digitally low-pass filtered (40 Hz, 12 db/oct., zero phase shift), and re-calculated to average reference. Channels were pooled to 14 regions of interest (ROIs; frontal left, frontal middle, frontal right [FL, FM, FR]; central left, central middle, central right [CL, CM, CR]; parietal left, parietal middle, parietal right [PL, PM, PR]; occipital middle [OM], occipito-temporal left, occipito-temporal right [OTL, OTR]; temporal left, temporal right [TL, TR]; see figure 3 in Wiese & Schweinberger, 2008). The mean number of trials was 52.1 (+/- 8.2 *SD*, *Min* = 30) in the co-occurrence/shared semantics, 51.5 (+/- 6.9 *SD*, *Min* = 36) in the no co-occurrence/shared semantics, 51.3 (+/- 8.0 *SD*, *Min* = 30) in the co-occurrence/no shared semantics, and 50.7 (+/- 7.2 *SD*, *Min* = 32) in the no co-occurrence/no shared semantics conditions.

To analyze N400, mean amplitude measures were derived from ERPs between 300 and 500 ms relative to target onset. Two later time windows were additionally analyzed from 500 to 600 ms and 600 to 700 ms. Separate repeated-measures analyses of variance (ANOVA) were performed at frontal, central, and parietal ROIs for these time windows. When appropriate, degrees of freedom were corrected according to the Huyn-Feldt procedure.

Results

Training sessions

Test performance during the training sessions (sessions 1 - 4) increased from approximately 50% correct responses in the first blocks to 84% correct responses during final testing (see figure 2). A repeated-measures ANOVA with the within-subjects factors training session (1 – 4), test block (blocks 1 – 5), and type of information (name, occupation, spare-time activity, favourite singer, place of living) revealed significant main effects of test block ($F[4,76] = 161.343$, $p < .001$, $\eta_p^2 = .895$) and type of information ($F[4,76] = 17.409$, $p < .001$, $\eta_p^2 = .478$). Further testing yielded an increase in performance across blocks, which can be described by a combination of linear ($F[1,19] = 444.152$, $p < .001$, $\eta_p^2 = .959$) and quadratic functions ($F[1,19] = 35.765$, $p < .001$, $\eta_p^2 = .653$). Post-hoc testing further revealed that occupations were remembered significantly better than names ($F[1,19] = 9.907$, $p = .005$, η_p^2

= .343), which were similar to favourite spare-time activities ($F < 1$). Moreover, spare-time activities were remembered more accurately than places of living ($F[1,19] = 9.729$, $p = .006$, $\eta_p^2 = .339$), which in turn were similar to favourite singers ($F < 1$; see also Table 1).

A repeated-measures ANOVA on final test accuracy for sessions 1 – 4 (see figure 2) with the within-subject factors session and type of information yielded a significant main effect of type of information ($F[4,76] = 17.409$, $p < .001$, $\eta_p^2 = .478$). Follow-up tests revealed similar memory for occupations and names ($F[1,19] = 1.966$, $p = .177$, $\eta_p^2 = .094$), which in turn were again similar to favourite spare-time activities ($F < 1$). Favourite spare-time activities were remembered more accurately than singers ($F[1,19] = 11.676$, $p = .003$, $\eta_p^2 = .381$), which in turn were similar to places of living ($F < 1$).

Finally, a repeated-measures ANOVA on accuracy in the fifth session prior to the priming experiment (see figure 2) revealed a significant main effect of information type ($F[4,76] = 8.928$, $p < .001$, $\eta_p^2 = .320$), reflecting most accurate memory for occupational information and poorest memory for favourite singers. Post-hoc tests revealed no significant differences between types of semantic information when tested pairwise with descending accuracy (see above; all $p > .1$). The percentage of correctly remembered semantic information (excluding names, which were idiosyncratic and thus not shared between individuals) was 81%. An additional item analysis revealed two or more correctly remembered semantic information units for 91% of the presented faces. At the same time, for 57% of the presented faces all four semantic information units were available.

Priming experiment

A repeated-measures ANOVA on mean correct reaction times in the priming experiment (see Table 1) with the factors prime type (co-occurrence/shared semantics, co-occurrence/no shared semantics, no co-occurrence/shared semantics, no co-occurrence/no shared semantics [unrelated]) and block (block 1, block 2, block 3) revealed significant main effects of prime type ($F[3,57] = 8.065$, $p < .001$, $\eta_p^2 = .298$) and block ($F[2,38] = 9.155$, $p < .001$, $\eta_p^2 = .325$), reflecting faster responses in block 1 relative to block 2 ($F[1,19] = 12.128$, $p = .002$, $\eta_p^2 = .390$), but not between block 2 and block 3 ($F[1,19] = 2.830$, $p = .109$, $\eta_p^2 = .130$). Moreover, response times were faster in the co-occurrence/shared semantics ($F[1,19] = 28.565$, $p < .001$, $\eta_p^2 = .601$), the no co-occurrence/shared semantics ($F[1,19] = 10.380$, $p = .004$, $\eta_p^2 = .353$), and in the co-occurrence/no shared semantics ($F[1,19] = 7.569$, $p = .013$, $\eta_p^2 = .285$) relative to the unrelated condition. Moreover, the omnibus ANOVA revealed a significant interaction of block x prime type ($F[6,114] = 2.759$, $p = .015$, $\eta_p^2 = .127$). For block 1, post-hoc tests revealed significantly faster responses in both co-occurrence/shared semantics ($F[1,19] = 7.064$, $p = .016$, $\eta_p^2 = .271$) and no co-occurrence/shared semantics conditions ($F[1,19] = 7.894$, $p = .011$, $\eta_p^2 = .294$) relative to the unrelated condition. In addition, a trend towards faster responses in the co-occurrence/no shared semantics condition was detected ($F[1,19] = 3.939$, $p = .062$, $\eta_p^2 = .172$). For block 2, faster responses relative to the unrelated condition were observed in the co-occurrence/shared semantics ($F[1,19] = 25.409$, $p < .001$, $\eta_p^2 = .572$), no co-occurrence/shared semantics ($F[1,19] = 10.813$, $p = .004$, $\eta_p^2 = .363$), co-occurrence/no shared semantics conditions ($F[1,19] = 15.594$, $p = .001$, $\eta_p^2 = .451$). Finally, in the third block, faster responses as compared to the unrelated condition were obtained in the co-occurrence/shared semantics condition ($F[1,19] = 10.184$, $p = .005$, $\eta_p^2 = .349$), but neither in the no co-occurrence/shared semantics nor in the co-occurrence/ no shared semantics conditions (both $F < 1$).

In the priming experiment, the mean percentage of correct familiarity decisions was between 80 and 90%, with no prominent differences between conditions (see Table 1). This level of performance is similar to what is typically reported for familiarity decisions for famous versus unfamiliar faces (e.g., Schweinberger, 1996; Wiese & Schweinberger, 2008), suggesting an adequate level of learning in the present study. A corresponding ANOVA on these data yielded a significant main effect of block, reflecting increasing accuracies from block 1 to block 2 (*F*[1,19] = 14.721, p = .001, η_p^2 = .437) and from block 2 to block 3 (*F*[1,19] = 4.504, p = .047, η_p^2 = .192), but neither a significant prime type effect (*F*[3,57] = 1.038, p = .378, η_p^2 = .052), nor a significant interaction (*F*[6,114] = 1.635, p = .170, η_p^2 = .079). Accordingly, there was no suggestion that the RT results could have been affected by a speed-accuracy trade-off.

In sum, combined co-occurrence and shared semantic information resulted in stronger and more consistent RT advantages than both purely semantic priming and purely associative priming.

Event-related potentials

An analysis of event-related potentials (see figures 3) was not possible for each block separately, as the number of trials per condition in each block (maximum possible = 20) was not sufficient. The analyses described below were therefore calculated on the basis of trials summed over experimental blocks.

N400 (300-500 ms): A repeated-measures ANOVA with the factors laterality (left, midline, right), site (frontal, central, parietal), and prime type revealed a significant main effect for prime type (*F*[3,57] = 3.850, p = .014, η_p^2 = .168). Follow-up testing yielded an N400 effect, with less negative amplitudes for the co-occurrence/shared semantics (*F*[1,19] = 13.316, p = .002, η_p^2 = .412), but neither for the co-occurrence/no shared semantics ($F < 1$) nor for the no co-occurrence/shared semantics (*F*[1,19] = 1.146, p = .298, η_p^2 = .057) relative to the unrelated condition (see figure 4). In addition, a trend for a significant interaction of site x laterality x prime type was observed (*F*[12,228] = 1.757, p = .088, η_p^2 = .085), potentially reflecting a mid fronto-central maximum of the N400 effect (see figure 5).[1]

[1] Following a reviewer comment, we additionally analyzed ERP data in the N400 time window at three single standard electrodes (Fz, Cz, Pz). A repeated-measures ANOVA revealed a significant main effect of prime type

500-600 ms. No significant effect of prime type was detected (main effect prime type: $F[3,57] = 2.184$, $p = .100$, $\eta_p^2 = .103$). A trend for a significant interaction of site x laterality x prime type was observed ($F[12,228] = 1.799$, $p = .082$, $\eta_p^2 = .086$).[2]

600-700 ms. Again, no main effect of prime type was found ($F < 1$). However, a significant interaction of site x laterality x prime type was observed ($F[12,228] = 2.244$, $p = .027$, $\eta_p^2 = .106$). Post-hoc ANOVAs with the within-subjects factor prime type carried out at each of the nine ROIs separately revealed a significant effect only at the right frontal ROI ($F[3,57] = 3.148$, $p = .032$, $\eta_p^2 = .142$), reflecting less negative amplitudes for the no co-occurrence/shared semantics versus unrelated ($F[1,19] = 5.228$, $p = .034$, $\eta_p^2 = .216$) and for the co-occurrence/shared semantics versus unrelated comparisons ($F[1,19] = 5.927$, $p = .025$, $\eta_p^2 = .238$), but not for the co-occurrence/no shared semantics versus unrelated comparison ($F < 1$).

Discussion

The present study examined semantic and associative priming in face recognition. We applied a learning paradigm and tested priming for newly established representations to unequivocally disentangle effects of shared semantic information from visual co-occurrence of prime and target stimuli. We found significant behavioural priming effects for both purely categorically and for purely associatively related prime/target pairs. When prime and target faces both shared semantic information and co-occurred during learning, priming tended to be stronger. Importantly, whereas the combined effect was independent of target face repetition, purely associative and purely semantic priming was not, but was not observed in the final test

($F[3,57] = 2.790$, $p = .049$, $\eta_p^2 = .128$), reflecting less negative amplitudes in co-occurrence/shared semantics relative to the unrelated condition ($F[1,19] = 6.821$, $p = .017$, $\eta_p^2 = .264$). Neither the co-occurrence/no shared semantics nor the no co-occurrence/shared semantics condition yielded significant priming effects.

[2] Please note that all learned faces were presented with equal frequency. Accordingly, the slightly more positive amplitude for the co-occurrence/shared semantics condition in this condition is unlikely to reflect a P3 oddball effect (for a review, see Polich, 2007), and more likely represents a prolonged effect from the previous N400 time window.

block. Furthermore, only combined effects of semantic relatedness and visual co-occurrence elicited a substantial and significant N400 priming effect. These findings suggest that both semantic relatedness and visual co-occurrence are important for the integration of new representations into the person-related semantic network.

While a number of previous studies reported purely categorical priming with famous faces or names (e.g., Carson & Burton, 2001; Stone & Valentine, 2007; Wiese & Schweinberger, 2008), the use of celebrity stimuli does not allow to test for priming effects exclusively based on co-occurrence (as celebrities who regularly co-occur typically also share semantic information). The present study demonstrates such priming effects in a learning paradigm with pre-experimentally unfamiliar faces, and is the first that demonstrates purely associative person priming at a short prime/target SOA, which renders expectancy-based effects highly unlikely[3]. The only previous learning study on semantic priming in person recognition (Vladeanu et al., 2006) used a long prime/target SOA, which makes the application of an expectancy-based strategy likely (Neely et al., 1989). Crucially, if participants respond faster because they expect a specific upcoming target, the resulting priming effect cannot be attributed to processes that are thought to reflect the structure of semantic memory, such as automatic spreading activation or semantic feature overlap (see Hutchison, 2003). Accordingly, in that case priming may say little about the organization of semantic representations (McNamara, 2005; Neely, 1977). The present finding of priming based on visual co-occurrence alone (but not based on expectancy) is of considerable theoretical relevance, as it supports the assumption of direct links between person identity representations (see Ellis, 1992). More specifically, the present results suggest that the simultaneous presentation of two faces is sufficient to establish a link between these faces, which is accordingly not semantic but rather purely associative in nature. Such a mechanism

[3] Although there probably is no universal SOA that separates strategic from non-strategic processing (Hutchison, 2003), SOAs of 250 ms (or less) have been suggested to prevent expectancy-based processes in a lexical decision task (Neely, 1977).

appears intuitively plausible, as we may associate two people that we regularly see together (e.g., on the bus), although we don't know who these people are, where they live etc. However, as units within the same pool are connected via inhibitory links in IAC models (Burton et al., 1990), priming based on co-occurrence cannot be explained by direct connections between two PINs. Alternatively, perceptual units for recognizing faces (so-called Face Recognition Units, FRU) of one person may get directly connected to a pre-semantic representation of the other person (i.e., the FRU, PIN, or both). Future studies will be necessary to clarify the exact mechanism underlying purely associative priming in person recognition.

It should be noted that although the present experimental setting with a short prime/target SOA substantially reduced the probability of expectancy-based strategies, the application of another strategic process – retrospective matching (Neely, 1991; Neely et al., 1989), cannot be definitely excluded. In a retrospective matching strategy, participants would try to determine whether prime and target are related after the presentation of the target. If so, the target has to be familiar, since relatedness cannot be detected for unfamiliar items. Whereas the detection of relatedness would thus bias a "familiar" response, its absence would bias an "unfamiliar" response, and accordingly a correct decision for an unrelated but familiar target will take longer than a correct response in a related condition. In our view, this mechanism is unlikely to explain the present data. If participants based their decision on matching semantic information, similarly efficient processing should have been apparent in the co-occurrence/shared semantics and the no co-occurrence/shared semantics conditions, while a less efficient response would be expected in the co-occurrence/no shared semantics condition. This, however, is not reflected in the present pattern of results. A corresponding case can be made for the suggestion that participants matched prime and target stimuli for co-occurrence during training. According to Neely (1991), if both expectancy- and matching-based strategies are unlikely, non-strategic co-activation of related representations seems to be the most parsimonious explanation of priming in the present study.

As noted above, our finding of a purely co-occurrence-based priming effect is not easy to integrate with the IAC model of person recognition (Burton et al., 1990), as this model assumes shared semantic information as the sole mechanism mediating priming. At the same time, the finding of a purely categorical effect is at deviance with alternative accounts, suggesting that only direct links established via co-occurrence can result in priming (Barry et al., 1998). Our behavioural findings rather suggest that both types of relatedness, i.e., both direct links between person representations established by visual co-occurrence and indirect links via higher order semantic units, reflect organizing principles of semantic person memory. This interpretation is in line with our finding of substantially stronger priming in the co-occurrence/shared semantics condition compared to the purely categorical or purely associative conditions. In the present study, enhanced priming cannot be explained on the basis of more shared semantic information in the combined relative to the no co-occurrence/shared semantics condition (see Carson & Burton, 2001), as the amount of shared semantic information was identical. Accordingly, the present "associative boost" appears to be truly associative in nature, and is likely related to co-occurrence during training.

Furthermore, priming in the co-occurrence/shared semantics condition was independent of target repetition and occurred in all three blocks, while this was not the case for priming based on co-occurrence or semantic relatedness alone. This finding is line with Bruce, Dench, & Burton (1993), who studied the effects of repetition on semantic priming. In this study, highly associated famous prime and target faces (e.g., Stan Laurel → Oliver Hardy) were used, which were therefore related via both shared semantics and visual co-occurrence. Bruce et al. (1993) found no interaction between repetition and associative priming, and interpreted this result as a confirmation of the IAC model's suggestion of independent loci for these effects. Applying this logic to the present study, priming of newly-learnt faces related via both visual co-occurrence and semantic information occurred at a different locus than repetition priming. Interestingly, this was not the case for the weaker priming effects elicited by co-occurrence and shared semantics alone, as neither of these effects was observed in the third block. These weaker forms of priming thus may be qualitatively different from the co-occurrence/shared semantics condition, and seem to occur at a different processing stage, which is modulated by stimulus repetition.

Interestingly, when explicitly asked to remember the learned information during training as well as prior to the priming experiment, participants were particularly accurate at remembering occupations and names. This may occur as contrasting with prior work, which found names particularly hard to remember (e.g., McWeeny, Young, Hay, & Ellis, 1987). It should be noted, however, that in the present study names were the only stimuli that were idiosyncratic; all other information units were shared by two people in the set, which presumably resulted in interference during explicit retrieval of shared semantic information. In addition, names were always presented first, and therefore may have attained more attention than the following semantic characteristics. Importantly, if explicit memory for semantic characteristics reflects the accessibility of the underlying representation, shared occupational information may be particularly well-suited to elicit categorical priming effects. This suggestion has to remain somewhat speculative, however, as priming resulting from different semantic categories was not directly tested in the present study.

The present ERP findings further emphasize the importance of a combination of categorical and associative relatedness – perhaps akin to typical encounters of relationships between people in real life – for semantic priming in person recognition. Neither the no co-occurrence/shared semantics, nor the co-occurrence/no shared semantics conditions elicited significantly more positive amplitudes than the unrelated condition in the N400 time range. A significant N400 effect was only observed in the co-occurrence/shared semantics relative to the unrelated condition. It thus appears that combined effects of both shared semantics and visual co-occurrence elicited N400 effects observed for 'associative' priming in previous studies (e.g., Schweinberger, 1996; Wiese & Schweinberger, 2008), and that both mechanisms typically contribute to such effects (but see Wiese & Schweinberger, 2011, for a purely categorical N400 effect with masked primes and a very short SOA). At the same time, no ERP priming effects for purely categorical or co-occurrence-based priming were observed. It should be noted that behavioural priming was relatively weak and inconsistent across blocks in these conditions, and that the temporal overlap of prime and target face processing may have obscured the detection of small ERP effects.

Although an interaction of prime type with electrode site was not statistically significant and only evident as a trend, the N400 effect in the present study appeared to have a frontal distribution (see also figure 5). While this is in line with previous reports of a relatively more frontal N400 effect for pictures relative to word stimuli (see Kutas & Federmeier, 2011), previous studies in face recognition typically revealed centro-parietal maxima (e.g., Schweinberger, 1996; Wiese & Schweinberger, 2008). These studies used celebrities as stimuli, which were presumably on average known for longer time periods and from a larger variety of occasions (e.g., from newspapers, TV, movies etc.) relative to the faces in the present study. It is therefore possible that a shift in the topography of the N400 priming effect towards more posterior scalp sites occurs with continued learning.

Generally in line with the suggestion of more frontally distributed effects for newly learned stimuli, similar results have been observed in a study on face recognition memory, in which faces were presented either with or without additional semantic information during learning (Paller, Gonsalves, Grabowecky, Bozic, & Yamada, 2000). In this study, faces learned with additional semantic information elicited more positive amplitudes relative to new faces at anterior sites between 300 and 600 ms, and this effect was not observed for faces learned without semantic information. Accordingly, the frontal effect was suggested to reflect the retrieval of semantic information, and frontal old/new effects in this time range have more generally been suggested to reflect conceptual priming (Paller, Voss, & Boehm, 2007; but see also Rugg & Curran, 2007). Interestingly for present purposes, recent evidence suggests that frontal old/new effects and the N400 may in fact represent identical neural and cognitive processes (Voss & Federmeier, 2011).

Furthermore, relative to previous studies (Schweinberger, 1996; Wiese & Schweinberger, 2008), the N400 effect in the present study was relatively small in amplitude, and this could be related to the effective prevention of expectancy-based strategies. It is known that N400 effects are attenuated but still evident when strategic processes can be ruled out (Kiefer, 2002; Kiefer & Spitzer, 2000; Rolke, Heil, Streb, & Hennighausen, 2001; Wiese & Schweinberger, 2011). We therefore suggest that the N400 priming effect in the co-occurrence/shared semantics relative to the unrelated condition reflects non-strategic processes, and that both direct links between the representations of newly learned people and indirect links via higher-order semantic information units are necessary to elicit the effect.

As discussed above, behavioural priming elicited in the co-occurrence/shared semantics condition was independent of target repetition (i.e., it occurred similarly in all three experimental blocks), which was not the case for purely semantic or purely co-occurrence-based priming. At the same time, only the co-occurrence/shared semantics condition yielded an ERP priming effect in the N400 time window. As we were not able to analyze our ERP data for each block separately, it may be possible that small N400 effects for semantic and co-occurrence based priming were present in the first two blocks, which were not strong enough to give rise to an effect when summing trials across blocks. At least for co-occurrence-based priming, this appears unlikely, given that ERPs in the N400 time range are virtually identical to the unrelated condition (see figure 4). Moreover, in a previous study (Wiese & Schweinberger, 2011) we found an N400 effect for purely semantically related stimuli using a very short SOA of 33 ms, which was not present at a longer SOA (1033 ms). It therefore remains possible, that N400 correlates of purely semantic (or categorical) priming occur at very short SOAs, but that this effect decays very quickly.

Finally, semantic relatedness elicited a relatively late right frontal effect, which was apparent independent of visual co-occurrence. Given its effect (600 – 700 ms), it is unlikely that the neuronal operations underlying this effect directly influenced priming as measured with response times. Interestingly, as it occurred for both conditions containing semantic relatedness, but not for visual co-occurrence alone, this effect might reflect a neural correlate of retrospective matching of prime and target semantic information (Neely et al., 1989). However, this interpretation is clearly speculative at present, and needs to be substantiated in further studies.

Future studies may also examine which brain regions yield semantic and associative priming effects in person recognition. As Gobbini and Haxby (2007) pointed out, anterior temporal regions typically show stronger activations for familiar than unfamiliar faces (see e.g., Gorno-Tempini et al., 1998; Leveroni et al., 2000; Sergent, Ohta, & Macdonald, 1992), which is commonly interpreted as reflecting the retrieval of biographical information. This is in line with studies on neuropsychological patients, who show deficits in accessing person-related semantic information after a lesion of the anterior temporal lobe (e.g., Ellis et al., 1989). Moreover, visual familiarity with faces has been associated with activations of the posterior cingulate and the precuneus (Leveroni et al., 2000; Natu & O'Toole, 2011). The combined effects of pre-activation in these regions reflecting semantic and visual face memory may underlie the N400 effect observed in the present study.

In conclusion, the present results indicate that both shared semantic information and visual co-occurrence reflect important organizing principles for person-related semantic memory. This conclusion is drawn from priming of newly learnt person representations, which may not fully reflect the stability and richness of representations established in real life. Importantly, however, the procedure chosen for the present experiment allowed completely disentangling effects of co-occurrence and semantic relatedness, which were confounded in most previous studies. ERP results suggest that both shared semantics and visual co-occurrence are necessary to elicit an N400 priming effect, further emphasizing the importance of both types of information for semantic person memory. Overall, our findings indicate that the cognitive system establishes qualitatively different types of links to embed new representations into the existing network, which may support the efficiency of semantic memory for people.

References

Barry, C., Johnston, R. A., & Scanlan, L. C. (1998). Are faces "special" objects? Associative and semantic priming of face and object recognition and naming. *Quarterly Journal of Experimental Psychology Section A-Human Experimental Psychology, 51*(4), 853-882.

Bentin, S., McCarthy, G., & Wood, C. C. (1985). Event-Related Potentials, Lexical Decision and Semantic Priming. *Electroencephalography and Clinical Neurophysiology, 60*(4), 343-355.

Bruce, V. (1983). Recognizing Faces. *Philosophical Transactions of the Royal Society of London Series B-Biological Sciences, 302*(1110), 423-436.

Bruce, V., Dench, N., & Burton, M. (1993). Effects of Distinctiveness, Repetition and Semantic Priming on the Recognition of Face Familiarity. *Canadian Journal of Experimental Psychology-Revue Canadienne De Psychologie Experimentale, 47*(1), 38-60.

Bruce, V., & Valentine, T. (1986). Semantic Priming of Familiar Faces. *Quarterly Journal of Experimental Psychology Section A-Human Experimental Psychology, 38*(1), 125-150.

Burton, A. M., Bruce, V., & Johnston, R. A. (1990). Understanding Face Recognition with An Interactive Activation Model. *British Journal of Psychology, 81*, 361-380.

Carson, D. R., & Burton, A. M. (2001). Semantic priming of person recognition: Categorial priming may be a weaker form of the associative priming effect. *Quarterly Journal of Experimental Psychology Section A-Human Experimental Psychology, 54*(4), 1155-1179.

Collins, A. M., & Loftus, E. F. (1975). Spreading Activation Theory of Semantic Processing. *Psychological Review, 82*(6), 407-428.

Dagenbach, D., Horst, S., & Carr, T. H. (1990). Adding New Information to Semantic Memory - How Much Learning Is Enough to Produce Automatic Priming. *Journal of Experimental Psychology-Learning Memory and Cognition, 16*(4), 581-591.

Ellis, A. W. (1992). Cognitive Mechanisms of Face Processing. *Philosophical Transactions of the Royal Society of London Series B-Biological Sciences, 335*(1273), 113-119.

Ellis, A. W., Young, A. W., & Critchley, E. M. (1989). Loss of memory for people following temporal lobe damage. *Brain, 112 (Pt 6)*, 1469-1483.

Gobbini, M. I., & Haxby, J. V. (2007). Neural systems for recognition of familiar faces. *Neuropsychologia, 45*(1), 32-41. doi: Doi 10.1016/J.Neuropsychologia.2006.04.015

Gorno-Tempini, M. L., Price, C. J., Josephs, O., Vandenberghe, R., Cappa, S. F., Kapur, N., & Frackowiak, R. S. J. (1998). The neural systems sustaining face and proper-name processing. *Brain, 121*, 2103-2118.

Hutchison, K. A. (2003). Is semantic priming due to association strength or feature overlap? A microanalytic review. *Psychonomic Bulletin & Review, 10*(4), 785-813. doi: Doi 10.3758/Bf03196544

Kiefer, M. (2002). The N400 is modulated by unconsciously perceived masked words: further evidence for an automatic spreading activation account of N400 priming effects. *Cognitive Brain Research, 13*(1), 27-39.

Kiefer, M., & Spitzer, M. (2000). Time course of conscious and unconscious semantic brain activation. *Neuroreport, 11*(11), 2401-2407.

Kutas, M., & Federmeier, K. D. (2011). Thirty Years and Counting: Finding Meaning in the N400 Component of the Event-Related Brain Potential (ERP). *Annual Review of Psychology, 62*, 621-647. doi: 10.1146/Annurev.Psych.093008.131123

Kutas, M., & Hillyard, S. A. (1980). Reading Senseless Sentences - Brain Potentials Reflect Semantic Incongruity. *Science, 207*(4427), 203-205.

Leveroni, C. L., Seidenberg, M., Mayer, A. R., Mead, L. A., Binder, J. R., & Rao, S. M. (2000). Neural systems underlying the recognition of familiar and newly learned faces. *Journal of Neuroscience, 20*(2), 878-886.

McClelland, J. L., & Rumelhart, D. E. (1981). An interactive activation model of context effects in letter perception: 1. An account of basic findings. *Psychological Review, 88*, 375-407.

McClelland, J. L., Rumelhart, D. E., & Hinton, G. E. (1986). *The appeal of parallel distributed processing*. Cambridge: MIT Press.

McNamara, T. P. (2005). *Semantic priming: perspectives from memory and word recognition*. New York: Psychology Press.

McRae, K., & Boisvert, S. (1998). Automatic semantic similarity priming. *Journal of Experimental Psychology-Learning Memory and Cognition, 24*(3), 558-572.

McWeeny, K. H., Young, A. W., Hay, D. C., & Ellis, A. W. (1987). Putting Names to Faces. *British Journal of Psychology, 78*, 143-149.

Meyer, D. E., & Schvaneveldt, R. W. (1971). Facilitation in Recognizing Pairs of Words - Evidence of a Dependence between Retrieval Operations. *Journal of Experimental Psychology, 90*(2), 227-234.

Minear, M., & Park, D. C. (2004). A lifespan database of adult facial stimuli. *Behavior Research Methods Instruments & Computers, 36*(4), 630-633.

Natu, V., & O'Toole, A. J. (2011). The neural processing of familiar and unfamiliar faces: A review and synopsis. *British Journal of Psychology, 102*, 726-747. doi: Doi 10.1111/J.2044-8295.2011.02053.X

Neely, J. H. (1977). Semantic Priming and Retrieval from Lexical Memory - Roles of Inhibition-Less Spreading Activation and Limited-Capacity Attention. *Journal of Experimental Psychology-General, 106*(3), 226-254.

Neely, J. H. (1991). Semantic priming effects in visual word recognition: A selective review of current findings and theories. In D. Besner & G. W. Humphreys (Eds.), *Basic processes in reading: Visual word recognition* (pp. 264-336). Hillsdale, NJ: Erlbaum.

Neely, J. H., Keefe, D. E., & Ross, K. L. (1989). Semantic Priming in the Lexical Decision Task - Roles of Prospective Prime-Generated Expectancies and Retrospective Semantic Matching. *Journal of Experimental Psychology-Learning Memory and Cognition, 15*(6), 1003-1019.

Oldfield, R. C. (1971). Assessment and Analysis of Handedness - Edinburgh Inventory. *Neuropsychologia, 9*(1), 97-113.

Paller, K. A., Gonsalves, B., Grabowecky, M., Bozic, V. S., & Yamada, S. (2000). Electrophysiological correlates of recollecting faces of known and unknown individuals. *Neuroimage, 11*(2), 98-110.

Paller, K. A., Voss, J. L., & Boehm, S. G. (2007). Validating neural correlates of familiarity. *Trends in Cognitive Sciences, 11*(6), 243-250.

Polich, J. (2007). Updating p300: An integrative theory of P3a and P3b. *Clinical Neurophysiology, 118*(10), 2128-2148. doi: Doi 10.1016/J.Clinph.2007.04.019

Rolke, B., Heil, M., Streb, J., & Hennighausen, E. (2001). Missed prime words within the attentional blink evoke an N400 semantic priming effect. *Psychophysiology, 38*(2), 165-174. doi: 10.1017/S0048577201991504

Rugg, M. D., & Curran, T. (2007). Event-related potentials and recognition memory. *Trends in Cognitive Sciences, 11*(6), 251-257.

Schweinberger, S. R. (1996). How Gorbachev primed Yeltsin: Analyses of associative priming in person recognition by means of reaction times and event-related brain potentials. *Journal of Experimental Psychology-Learning Memory and Cognition, 22*(6), 1383-1407.

Schweinberger, S. R., & Burton, A. M. (2003). Covert recognition and the neural system for face processing. *Cortex, 39*(1), 9-30.

Schweinberger, S. R., Pfütze, E. M., & Sommer, W. (1995). Repetition Priming and Associative Priming of Face Recognition - Evidence from Event-Related Potentials. *Journal of Experimental Psychology-Learning Memory and Cognition, 21*(3), 722-736.

Sergent, J., Ohta, S., & Macdonald, B. (1992). Functional Neuroanatomy of Face and Object Processing - A Positron Emission Tomography Study. *Brain, 115*, 15-36.

Stone, A. (2008). Categorical priming of famous person recognition: a hitherto overlooked methodological factor can resolve a long-standing debate. *Cognition, 108*(3), 874-880.

Stone, A., & Valentine, T. (2007). The categorical structure of knowledge for famous people (and a novel application of the Centre-Surround theory). *Cognition, 104*, 535-564.

Thompson, S. A., Graham, K. S., Williams, G., Patterson, K., Kapur, N., & Hodges, J. R. (2004). Dissociating person-specific from general semantic knowledge: roles of the left and right temporal lobes. *Neuropsychologia, 42*(3), 359-370.

Tranel, D., Damasio, H., & Damasio, A. R. (1997). A neural basis for the retrieval of conceptual knowledge. *Neuropsychologia, 35*(10), 1319-1327.

Vladeanu, M., Lewis, M., & Ellis, H. (2006). Associative priming in faces: Semantic relatedness or simple co-occurrence? *Memory & Cognition, 34*(5), 1091-1101.

Voss, J. L., & Federmeier, K. D. (2011). FN400 potentials are functionally identical to N400 potentials and reflect semantic processing during recognition testing. *Psychophysiology, 48*(4), 532-546. doi: 10.1111/J.1469-8986.2010.01085.X

Wiese, H. (2011). The structure of semantic person memory: Evidence from semantic priming in person recognition. *British Journal of Psychology, 102*(4), 899-914.

Wiese, H., & Schweinberger, S. R. (2008). Event-related potentials indicate different processes to mediate categorical and associative priming in person recognition.

Journal of Experimental Psychology-Learning Memory and Cognition, 34(5), 1246-1263.

Wiese, H., & Schweinberger, S. R. (2011). Accessing semantic person knowledge: Temporal dynamics of nonstrategic categorical and associative priming. *Journal of Cognitive Neuroscience, 23*(2), 447-459.

Young, A. W., Flude, B. M., Hellawell, D. J., & Ellis, A. W. (1994). The Nature of Semantic Priming Effects in the Recognition of Familiar People. *British Journal of Psychology, 85*, 393-411.

Figure Captions

Figure 1. Illustration of the experimental paradigm.

Figure 2. Accuracies from the different blocks and the final test during training, as well as from the pre-priming test block in session 5. Data from the training phase is averaged across the four sessions. Error bars depict standard errors of the mean.

Figure 3. Grand mean event-related potentials at frontal left (FL), frontal middle (FM), frontal right (FR), central left (CL), central middle (CM), central right (CR), parietal left (PL), parietal middle (PM), and parietal right (PR) regions of interest. Solid lines indicate prime (-200 ms) and target onset (0 ms), respectively. The dashed lines indicates the 300 – 500 ms time window, in which a significant priming effect for the co-occurrence/shared semantics condition was observed.

Figure 4. Grand mean event-related potentials at right frontal (FR) and central middle (CM) regions of interest. Shaded areas reflect time windows in which significant effects were found for the co-occurrence/shared semantics (300 – 500 ms, 600 – 700 ms) and for the no co-occurrence/shared semantics (600 – 700 ms) relative to unrelated conditions.

Figure 5. Scalp-topographical voltage maps (90° equidistant projection, spherical spline interpolation) of priming effects (related – unrelated conditions) from 200 to 700 ms relative to target onset.

Table 1. Behavioural results of the priming experiment. SEM = standard error of the mean.

		co-occ./ shared sem.	no co-occ./ shared sem.	co-occ./ no shared sem.	no co-occ./ no shared sem.
Block 1					
Response Times (ms)					
	Mean	654.3	651.1	658.1	674.9
	SEM	18.9	15.5	15.9	18.5
Accuracies					
	Mean	.88	.87	.83	.84
	SEM	.04	.02	.03	.03
Block 2					
Response Times (ms)					
	Mean	612.3	625.5	620.2	646.6
	SEM	19.8	17.8	18.8	18.9
Accuracies					
	Mean	.89	.89	.89	.86
	SEM	.03	.03	.03	.03
Block 3					
Response Times (ms)					
	Mean	596.3	621.4	617/8	615.9
	SEM	21.2	19.4	18.6	22.8
Accuracies					
	Mean	.90	.90	.90	.91
	SEM	.03	.03	.03	.02

Figure 1

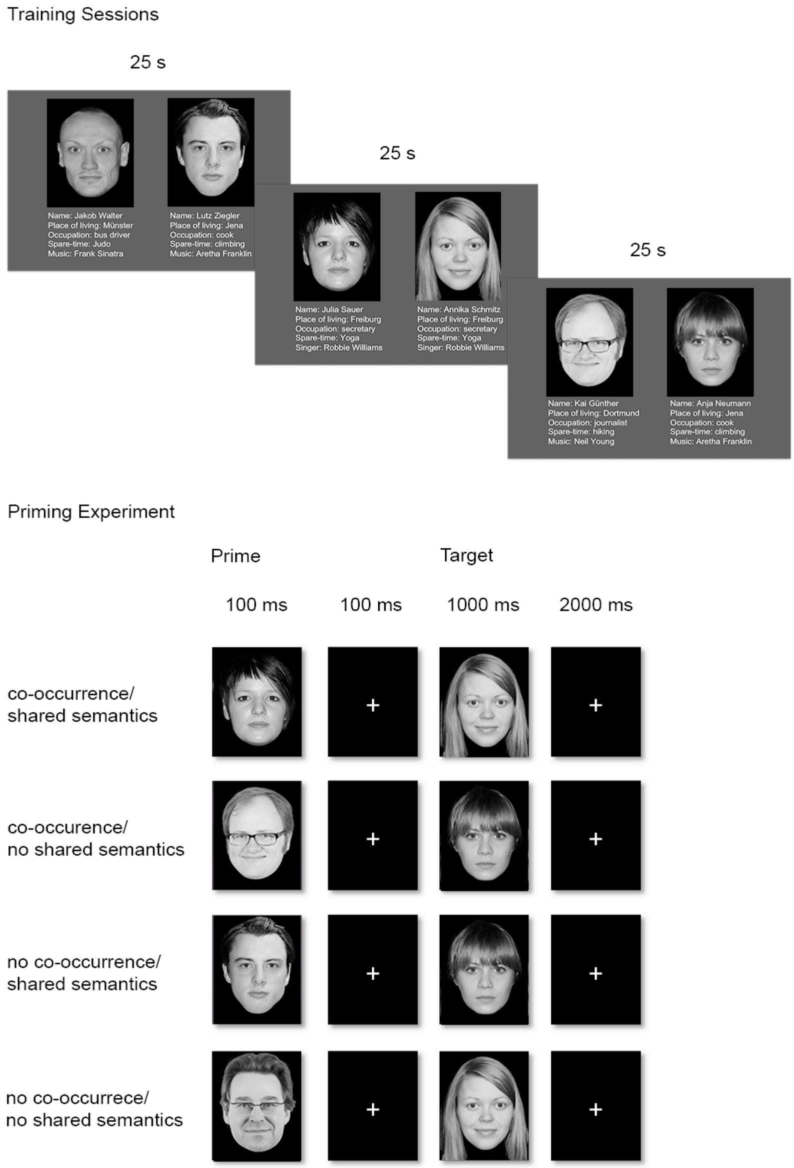

Training Sessions
25 s
Name: Jakob Walter
Place of living: Münster
Occupation: bus driver
Spare-time: Judo
Music: Frank Sinatra
Name: Lutz Ziegler
Place of living: Jena
Occupation: cook
Spare-time: climbing
Music: Aretha Franklin
25 s
Name: Julia Sauer
Place of living: Freiburg
Occupation: secretary
Spare-time: Yoga
Singer: Robbie Williams
Name: Annika Schmitz
Place of living: Freiburg
Occupation: secretary
Spare-time: Yoga
Singer: Robbie Williams
25 s
Name: Kai Günther
Place of living: Dortmund
Occupation: journalist
Spare-time: hiking
Music: Neil Young
Name: Anja Neumann
Place of living: Jena
Occupation: cook
Spare-time: climbing
Music: Aretha Franklin
Priming Experiment
Prime
Target
100 ms
100 ms
1000 ms
2000 ms
co-occurrence/
shared semantics
co-occurence/
no shared semantics
no co-occurrence/
shared semantics
no co-occurrece/
no shared semantics
+

Figure 2

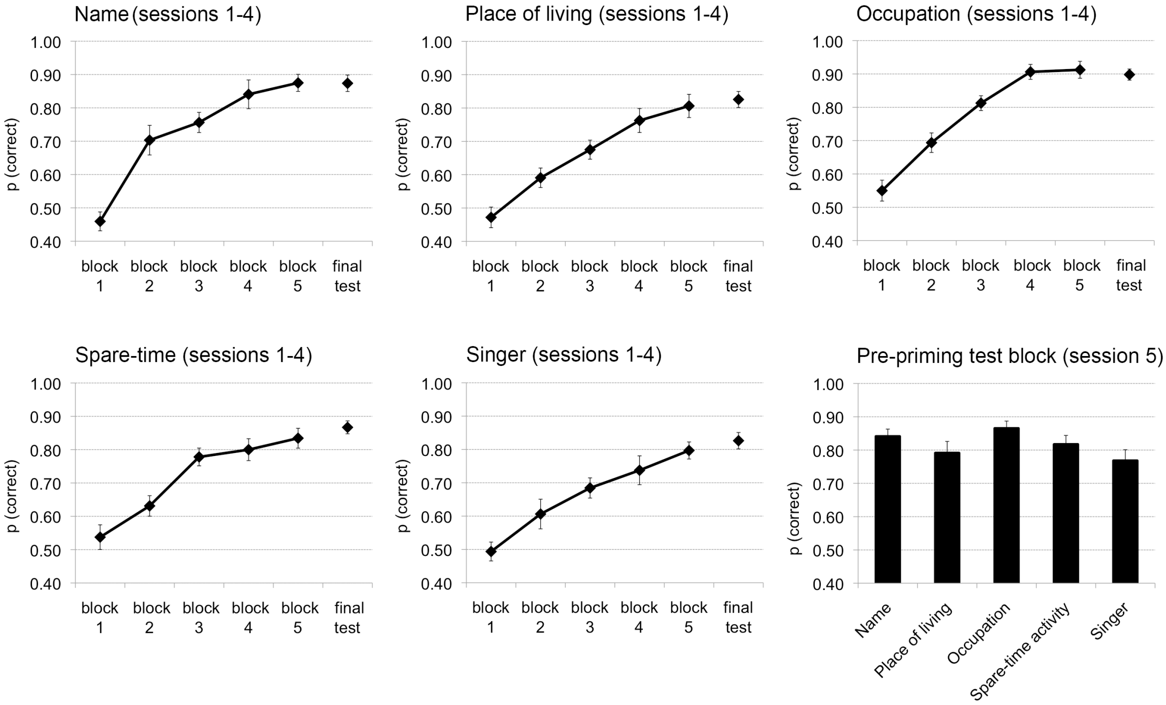
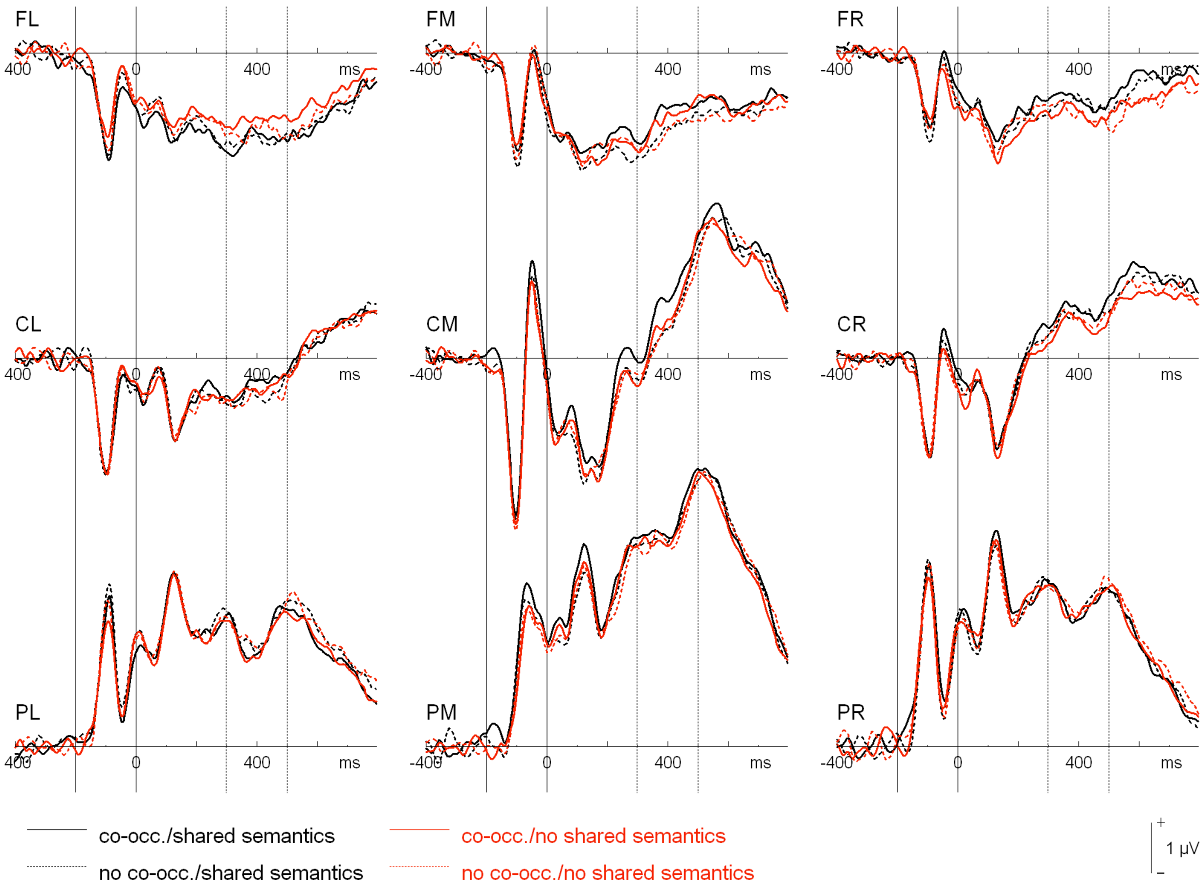

Name (sessions 1-4)
Place of living (sessions 1-4)
Occupation (sessions 1-4)
Spare-time (sessions 1-4)
Singer (sessions 1-4)
Pre-priming test block (session 5)
p (correct)
1.00
0.90
0.80
0.70
0.60
0.50
0.40
block 1
block 2
block 3
block 4
block 5
final test
Name
Place of living
Occupation
Spare-time activity
Singer

Figure 3



FL
FM
FR
CL
CM
CR
PL
PM
PR
-400
0
400
ms
co-occ./shared semantics
no co-occ./shared semantics
co-occ./no shared semantics
no co-occ./no shared semantics
+
1 μV
–

Figure 4

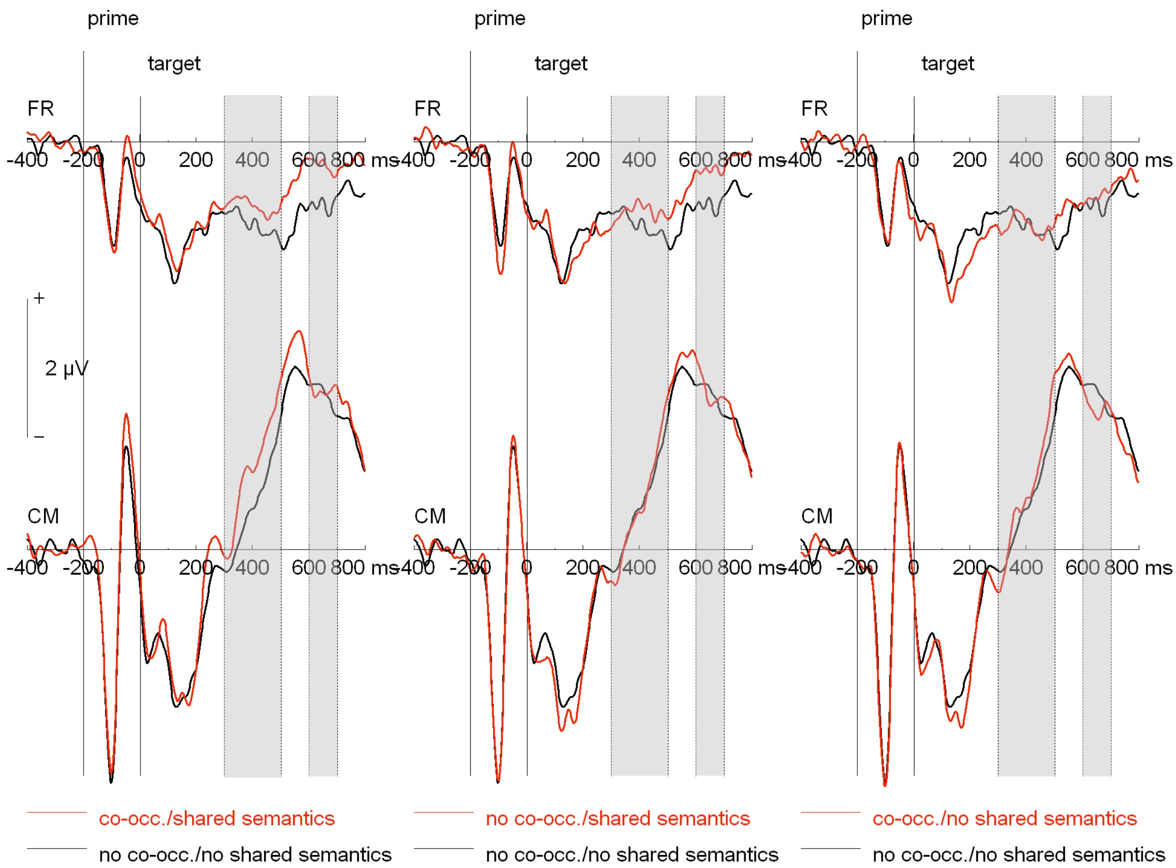
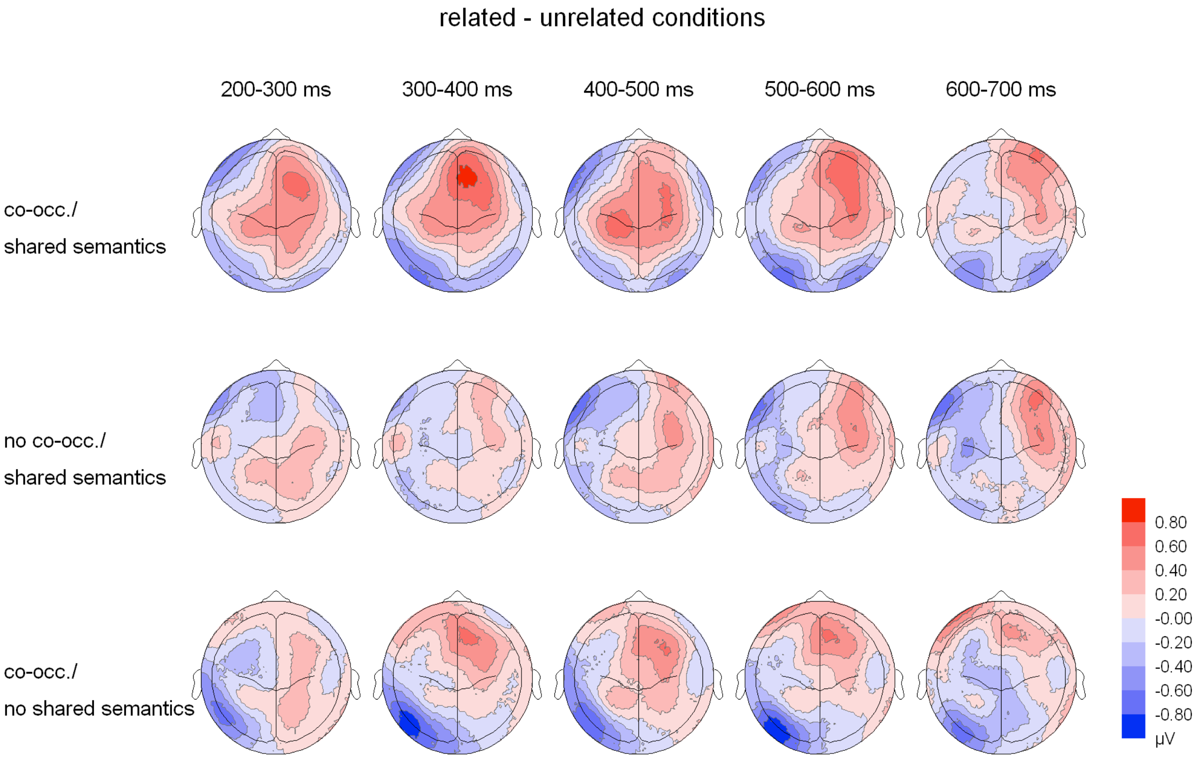

prime
target
FR
-400
-200
0
200
400
600
800 ms
+
2 µV
–
CM
co-occ./shared semantics
no co-occ./no shared semantics
no co-occ./shared semantics
no co-occ./no shared semantics
co-occ./no shared semantics
no co-occ./no shared semantics

Figure 5


related - unrelated conditions
200-300 ms
300-400 ms
400-500 ms
500-600 ms
600-700 ms
co-occ./
shared semantics
no co-occ./
shared semantics
co-occ./
no shared semantics
0.80
0.60
0.40
0.20
-0.00
-0.20
-0.40
-0.60
-0.80
µV